Graphing

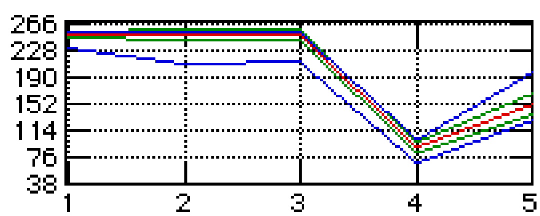
Preparation Reading:

The histograms you will be studying are of the reflectance values at each of the 5 wavelengths the satellite measures. On the horizontal scale the numbers 1 through 5 refer respectively to the blue, green, red, near-infrared, and mid-infrared wavelengths. The vertical scale ranges from 0 (no reflectance) to 255 (maximum reflectance). Sometimes the vertical scale will go beyond 255, but the values plotted never exceed 255. Note that the graph really only has meaning when read at the horizontal positions of 1, 2, 3, 4, or 5. The line segments which connect the points don't represent reflectance values of other wavelengths. They simply make the graph easier to read.

The red line is the average of the reflectance of all the pixels in the selected area. The green lines mark off all reflectance within 1 standard deviation of the average, and the blue lines mark the minimum and maximum values. A formal definition of standard deviation is not developed. You are simply instructed that the green lines contain about 66% of the reflectance in the selected area.

Mathematically the primary emphasis should be on the interpretation of graphs. You will be viewing graphs that are automatically scaled to fill the window. While convenient, this feature can be confusing as the vertical scale can change dramatically from one region to the next. So although two graphs may look the same their vertical scales could be vastly different. This phenomenon highlights the difference between two graphs having the same relative shape but different absolute shapes.

For example, consider the two graphs on the following page, while the relative shapes are about the same, the absolute shapes are very different. The histogram on the left has a dip on band 4 as does the histogram on the right, however, the dip on the histogram on the right is very small compared to the one on the left! Note that the dip on the right actually looks larger than the dip on the left. It is when we look carefully at the vertical scales, however, that we discover that the dip on the left is a change of almost 200 intensity values while the dip on the right is of only 9 intensity values! The dips are in the same relative position on both graphs but of very different absolute sizes.



How can we classify and discriminate between regions on an image using histograms?

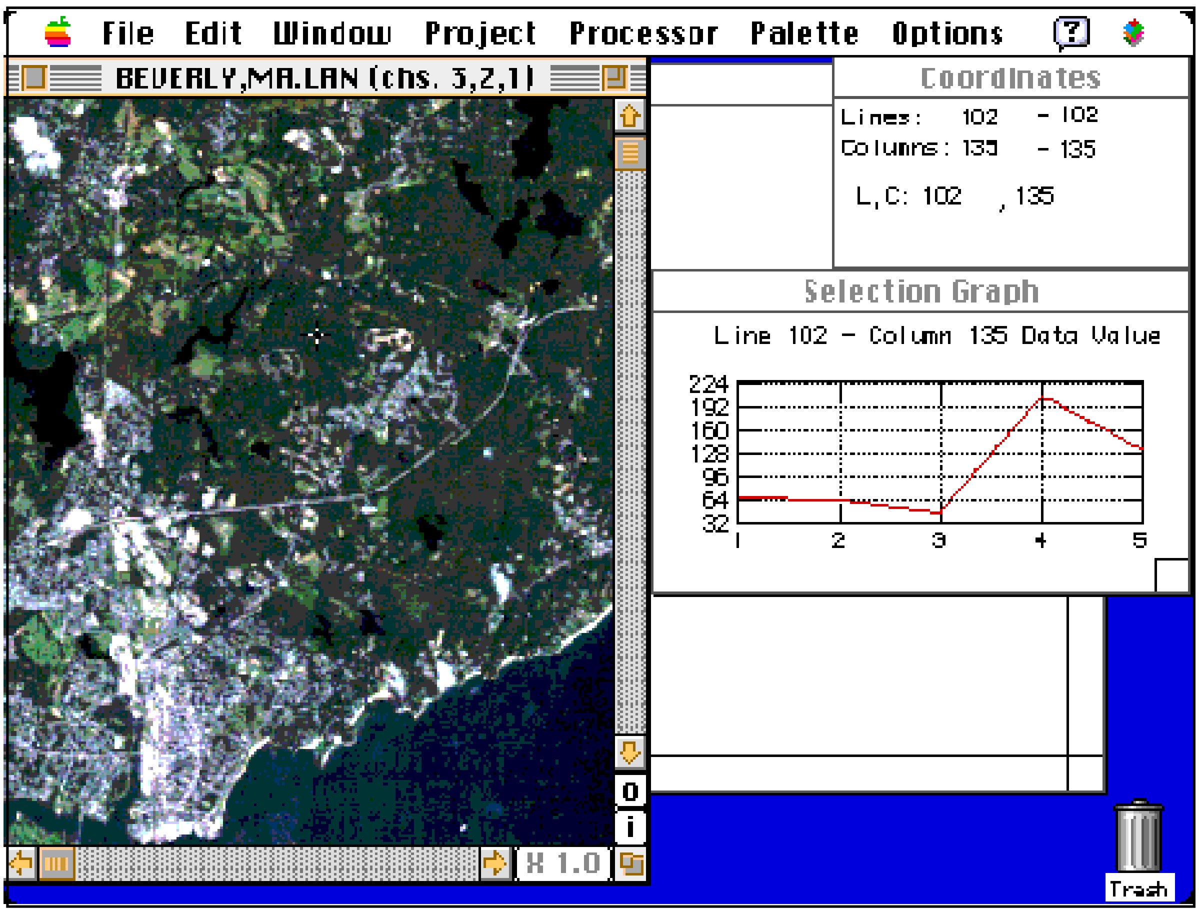
By now you should understand that the images we have been studying are based on numbers that represent the intensity of reflected light at five different wavelengths. Stretching the image and assigning various colors to different wavelengths helped us discriminate between similar looking regions that were in fact different. But some regions still may appear similar on the computer screen even though they represent different objects on earth. In this lesson we learn how to use another tool of the MultiSpec program to help us classify regions, and discriminate between different regions.

Which of These Things Doesn't Belong?

At the computer, start the MultiSpec program and open an image of Beverly, MA. Assign the colors red, green, and blue to bands 3,2,1 to generate a true color image.

Now choose **Show Selection Coordinates** from the **Options** menu. Now select **New Selection Graph** from the **Options** menu. Click anywhere on the image window to highlight it, and click again on any one pixel of the image.

By re-sizing the windows (lower right box of a window) and moving the windows around the desktop (drag the window by its title bar) arrange the windows so that they appear similar to the figure on the next page.



Coordinates Window

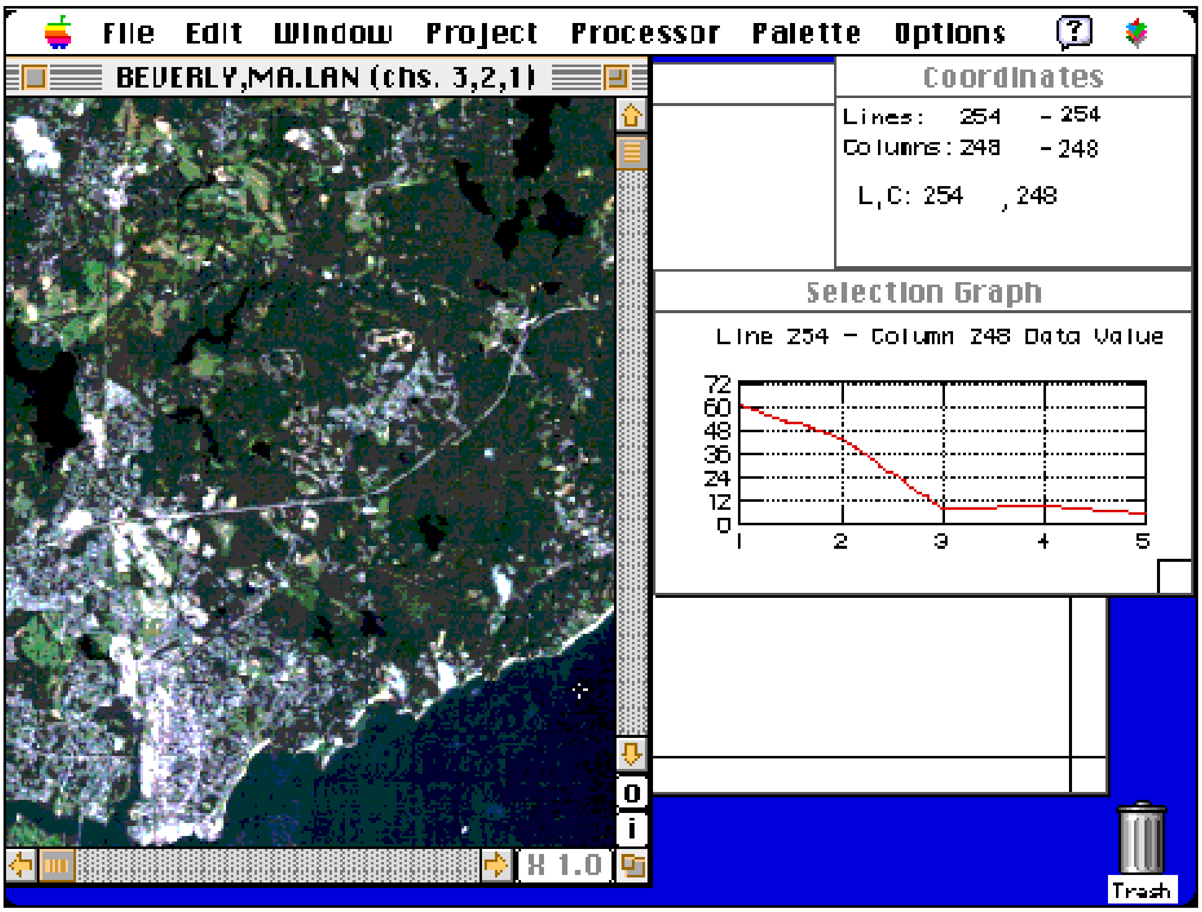
In the upper right hand corner of the figure above is the Coordinates window. This window allows you to know exactly what part of the image you are selecting when you click on the image window. The coordinates of the cursor are given as an ordered pair with the line number given first and the column number given second. In this figure the pixel selected is the one at (102, 135). Depending on the magnification factor you are using you may have to use the scroll bars on the image window to find a particular pixel.

Selection Graph

Below the Coordinates Window is the Selection Graph window. This is the window you should learn to use during this computer session. It is a graph of the reflectance values of the pixel (or pixels) you have selected. In the above figure the graph is for the pixel located at (102,135).

This graph provides valuable analytical information. The bottom axis has labels 1, 2, 3, 4, and 5 that correspond to the blue, green, red, near-infrared, and mid-infrared wavelengths that Landsat monitors. The vertical scale corresponds to the numerical value of the reflectance. This scale can range from 0 to 255. A 0 would represent very little reflected light and a 255 would represent a lot of reflected light. Remember that these values may be the result of stretching the data. The pixel we have selected is brightest in bands 4, and darkest in band 3. This means that the object at this location on the earth is reflecting more near-infrared light than light of the other wavelengths.

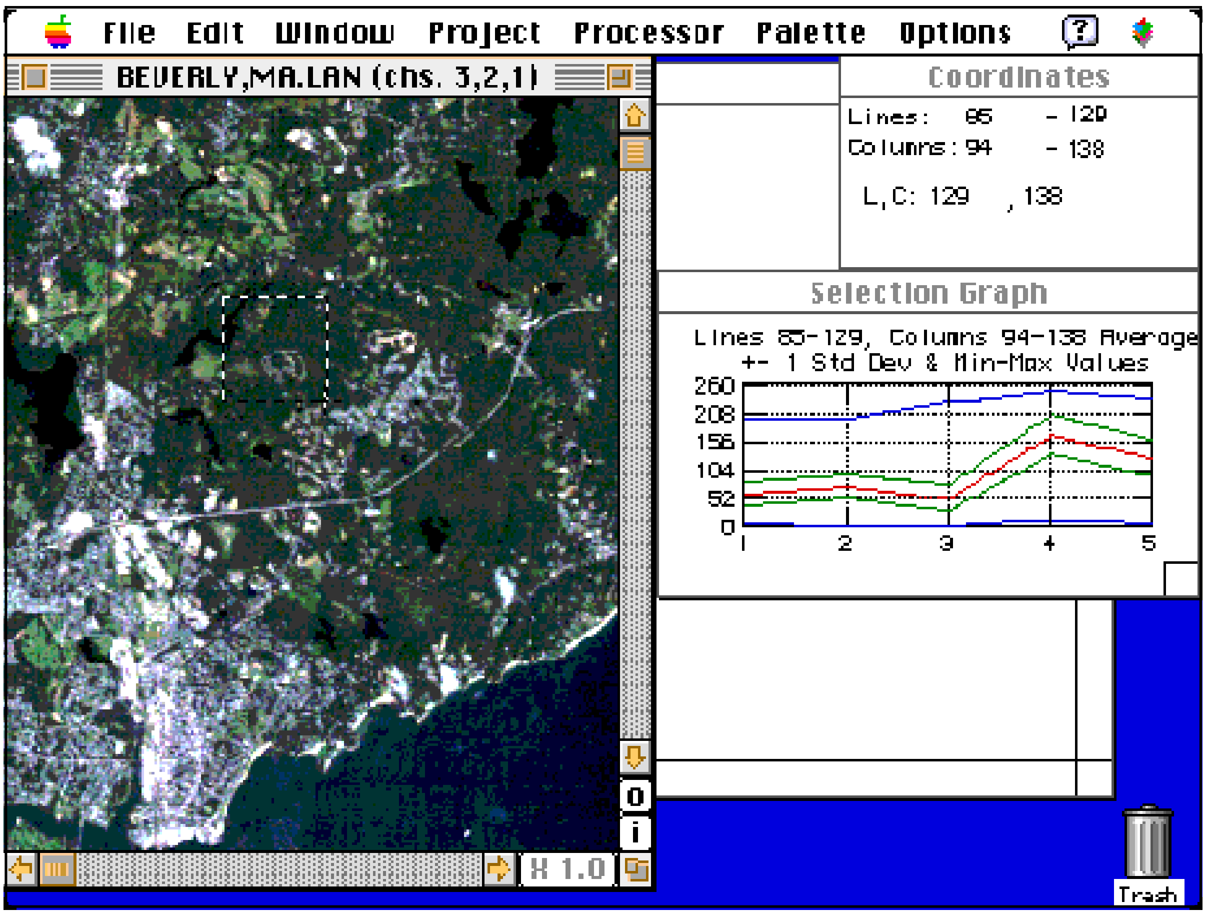
Now click anywhere on the image window to activate it. Then click on the pixel with coordinates (L,C) = (254,248) that is down on the ocean. At this point we find reflectances of about 60, 44, 10, 11, and 6. See figure below for an idea of what your screen should resemble.



Note that the reflectances are lower at every one of the five bands than for the previous pixel at (102,135).

This difference makes sense since we expect the ocean to be darker than ground. If you have ever flown over ocean and trees you will have noticed how the ocean appears almost black while the trees do appear brighter. The fact that water absorbs most all of the energy that falls on it can help us determine if an unknown dark region is water or not.

Now click and drag in the image window to select a rectangle of many pixels. We selected a rectangle with its upper left corner at pixel (L,C) = (85,94) and its lower right corner at (L,C) = (129,138). Try to select these same pixels for the upper left and lower right corners of your rectangle. The result should resemble the figure



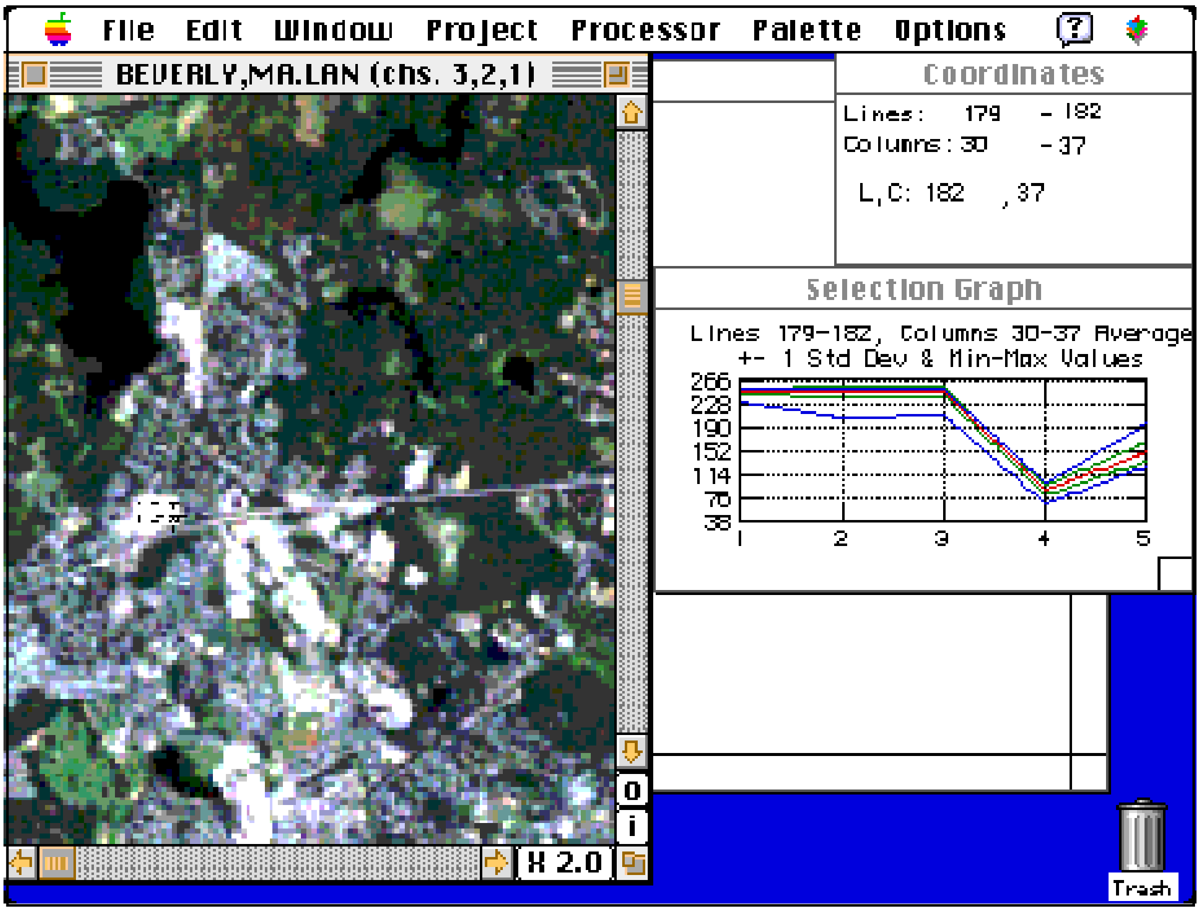
Note that now the selection graph contains 5 lines. The red line is the average of the reflectance of all the pixels in the rectangle we selected. The green lines mark off a range that contains the middle 66% of the reflectance values. The blue lines indicate where the minimum and maximum values are for the reflectance of all the pixels we selected.

For example look at the reflectance on band 4. Of all the pixels selected in the rectangle the lowest reflectance is about 10, the highest reflectance value is around 255, 66% of the reflectance is between 130 and 208, and the average reflectance is about 160.

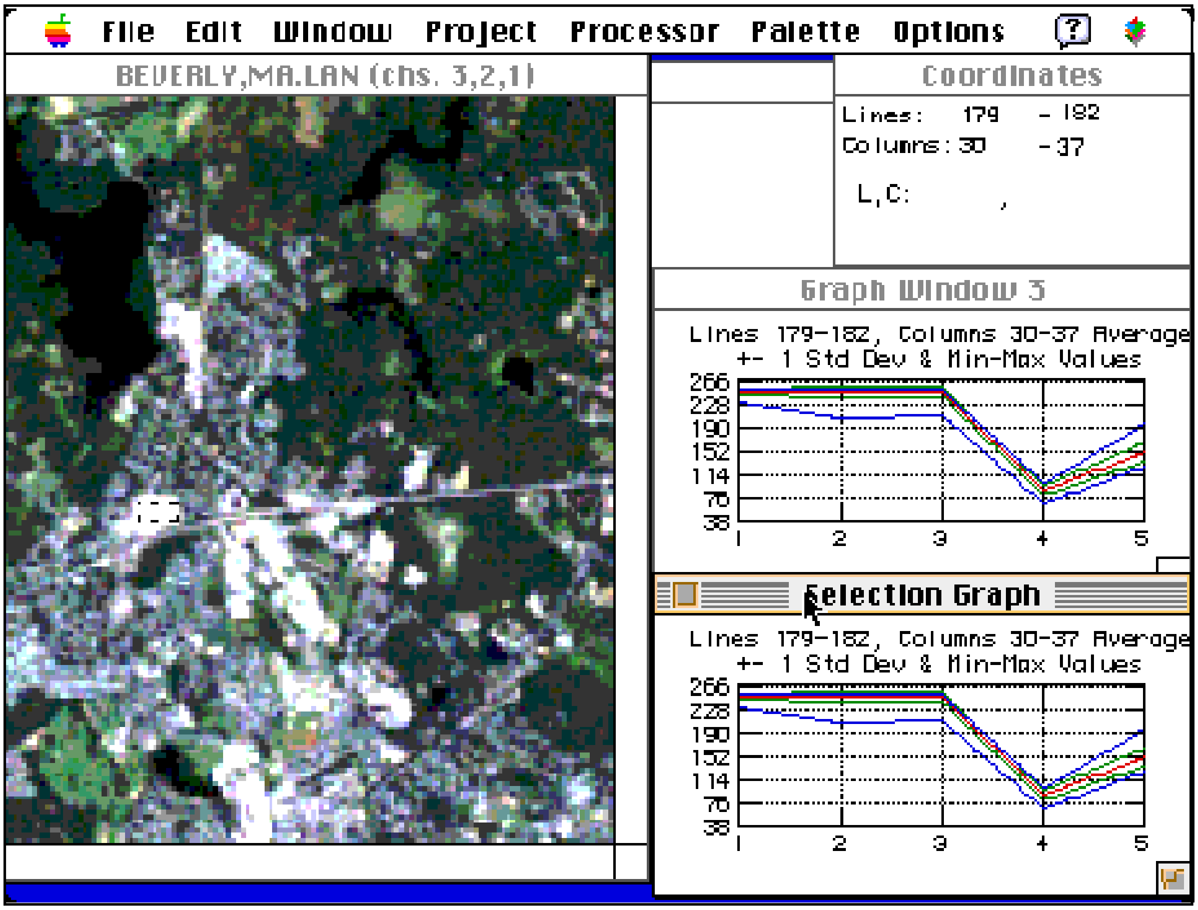
Using the Histogram Window to Discriminate Between Different Regions

We can use the histogram window to help us identify similar and different regions. What we will do is find an area of interest and save its histogram to compare with a second histogram of another area of interest.

Go to a magnification of **X2.0**. Click and drag the mouse to select a rectangle with upper left corner (L,C) = (179,30) and lower right corner (L,C) = (182,37). Your screen should resemble the figure below.

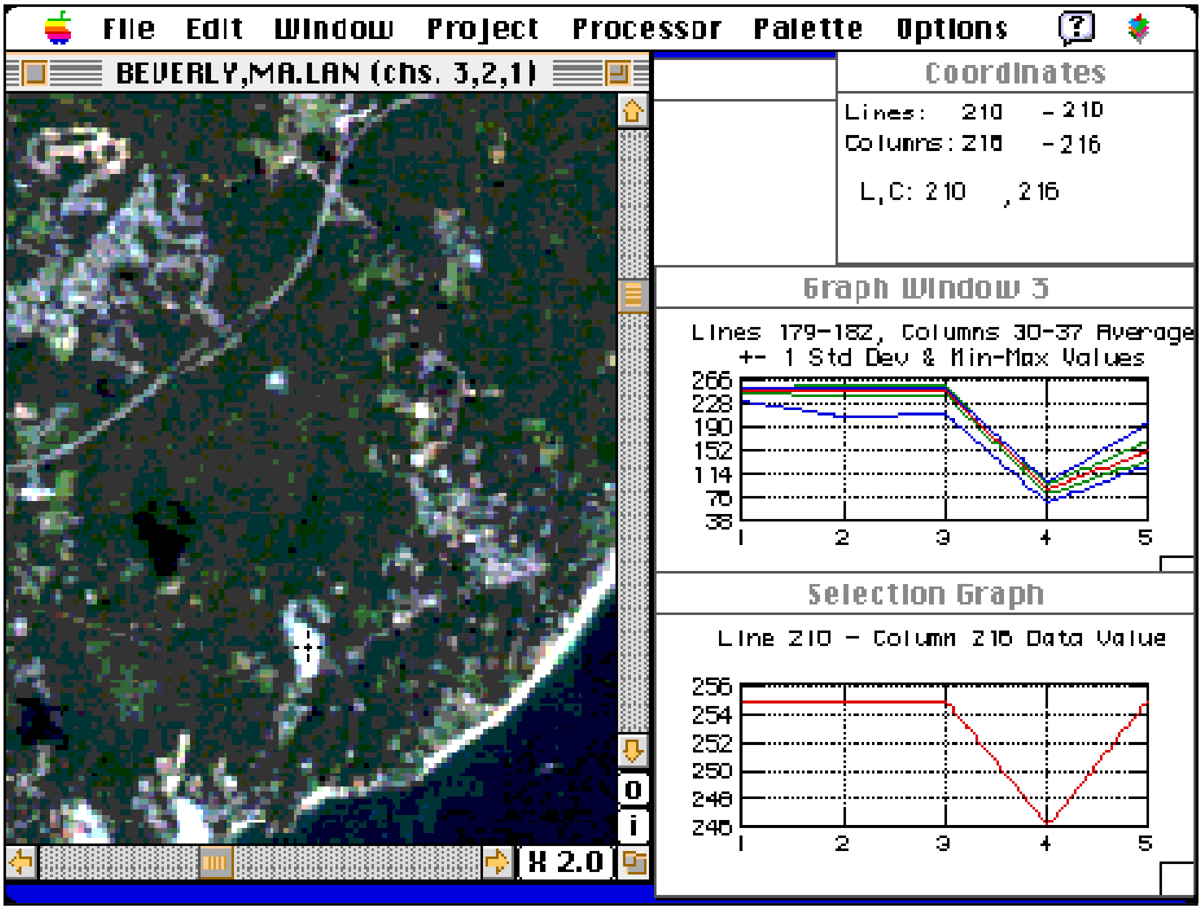


Now choose **Keep Selection Graph** from the **Options** Menu. A new selection graph appears and the old selection graph will remain fixed even if you select a new set of pixels. Position the second selection graph below the first graph so that your display resembles the figure below.



After your screen looks similar to the one in the figure above, click in the image window to activate it, and then click on an image pixel. Note that the top graph stays the same and only the bottom graph changes. Displaying both graphs allows us to compare the histogram of a new region with the saved histogram of the white region visible in the image. This white region is near a road and in the city limits of Beverly. It is very likely that this bright area is caused by light reflecting off large buildings with metal or concrete roofs.

Select just the one pixel at (L,C) = (210,216). This is a pixel in another white region. It is well outside the town of Beverly. Could this white area also be buildings? Let's compare this region's histogram with the first histogram and try to decide if the objects are the same or different. After selecting the pixel at (L,C) = (210,216) your screen should resemble the figure that follows.



Absolute and Relative Differences

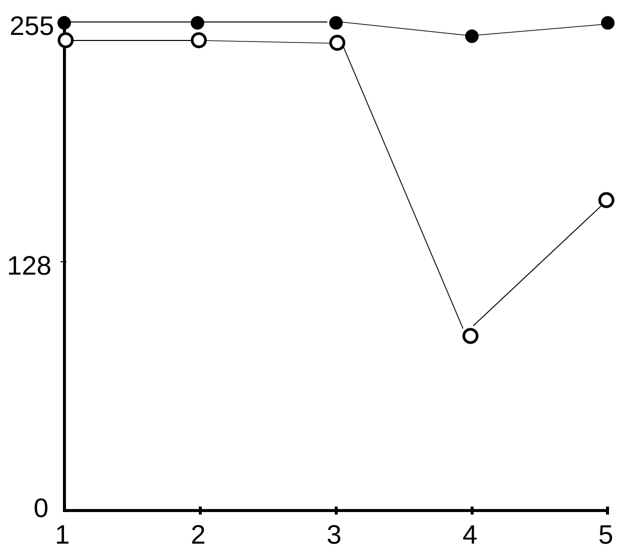
In the figure above the top graph is of the bright object in the city of Beverly and the graph on the bottom is the histogram of the bright image located where the cross-hair cursor is located at pixel (210,216). Are these bright white regions the same? Their graphs look very similar. Both graphs have a "dip" on band 4.

If we were in a hurry we might conclude from the graphs that these objects are the same. If it was really important to know what was at these locations we of course would do some ground truthing. Sometimes though, ground truthing might be expensive or impractical. In these cases a closer examination of the graphs will have to be our only clue to the identity of the objects.

Look more closely at the two graphs. In particular notice the vertical scales. The MultiSpec program automatically chooses the minimum and maximum values for the vertical reflectance scale. The result is that we may be looking at a very small portion of the entire scale. The advantage is that we see only the portion of the scale that is relevant for the region we have selected. The disadvantage is that comparing two graphs with different scales can be confusing.

Notice that the top graph drops from the upper 200's on bands 1-3 down to about 90 on band 4. The bottom graph drops from 255 on bands 1-3 to 246 on band 4. This drop is very slight in absolute terms since it is only a difference of 9 reflectance levels. The drop on the other graph is much greater in absolute terms. On the top graph the drop is about 150 reflectance levels! When the differences are viewed absolutely the two graphs are very different.

The reason the graphs initially appeared the same was because we reacted to the similar relative shape of the two graphs. Both graphs do have "dips" at band 4. To make the difference between the graphs more apparent we can plot the two graphs on axes with the same scale as in the figure below.



The object with the large drop in reflectance on band 4 is reflecting very little infrared energy. The histogram of the other object indicates that it is reflecting a lot of energy at all wavelengths measured by Landsat.

The moral of the story is to be sure whether or not the similarity you notice between two graphs is a relative or an absolute similarity (or difference).

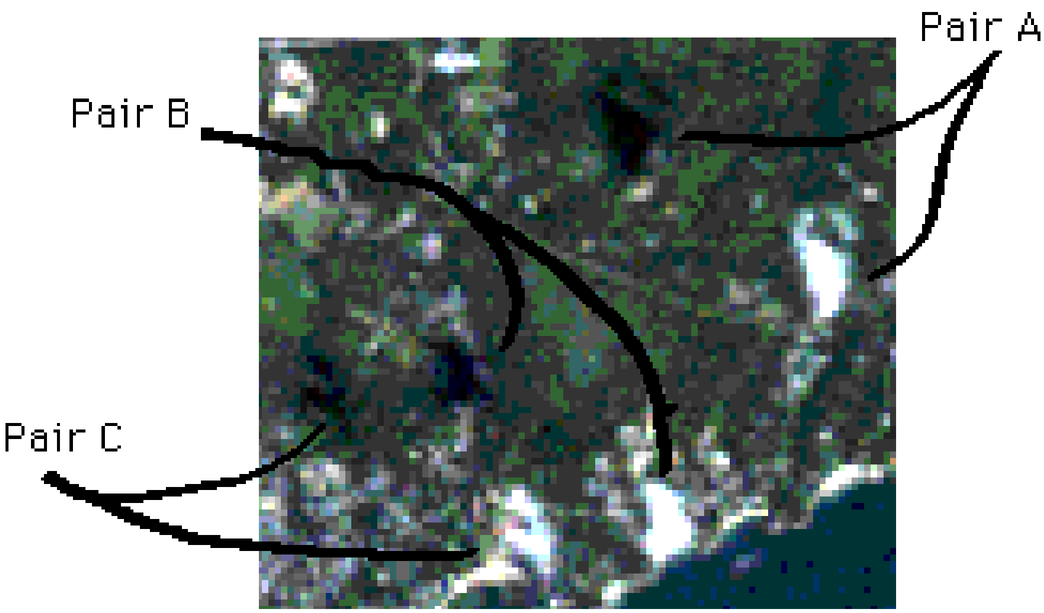
Another Discrimination Exercise

The bright objects to the left of the screen (downtown Beverly) are most likely buildings. We now have evidence (the histograms) that suggest that the bright areas at the right of the screen are not buildings. We have discriminated between two similar appearing but different objects.

But what is that bright feature to the right of the screen?

Use a magnification of **X2.0** and place the unknown bright area near the center of the image window. Notice the three pairs of dark and light regions. The alignment of the three pairs is identical. The dark region is always the same distance away towards the upper left corner of the screen relative to the bright regions. If it hasn't occurred to you already, might these pairs of objects be clouds and their shadows?

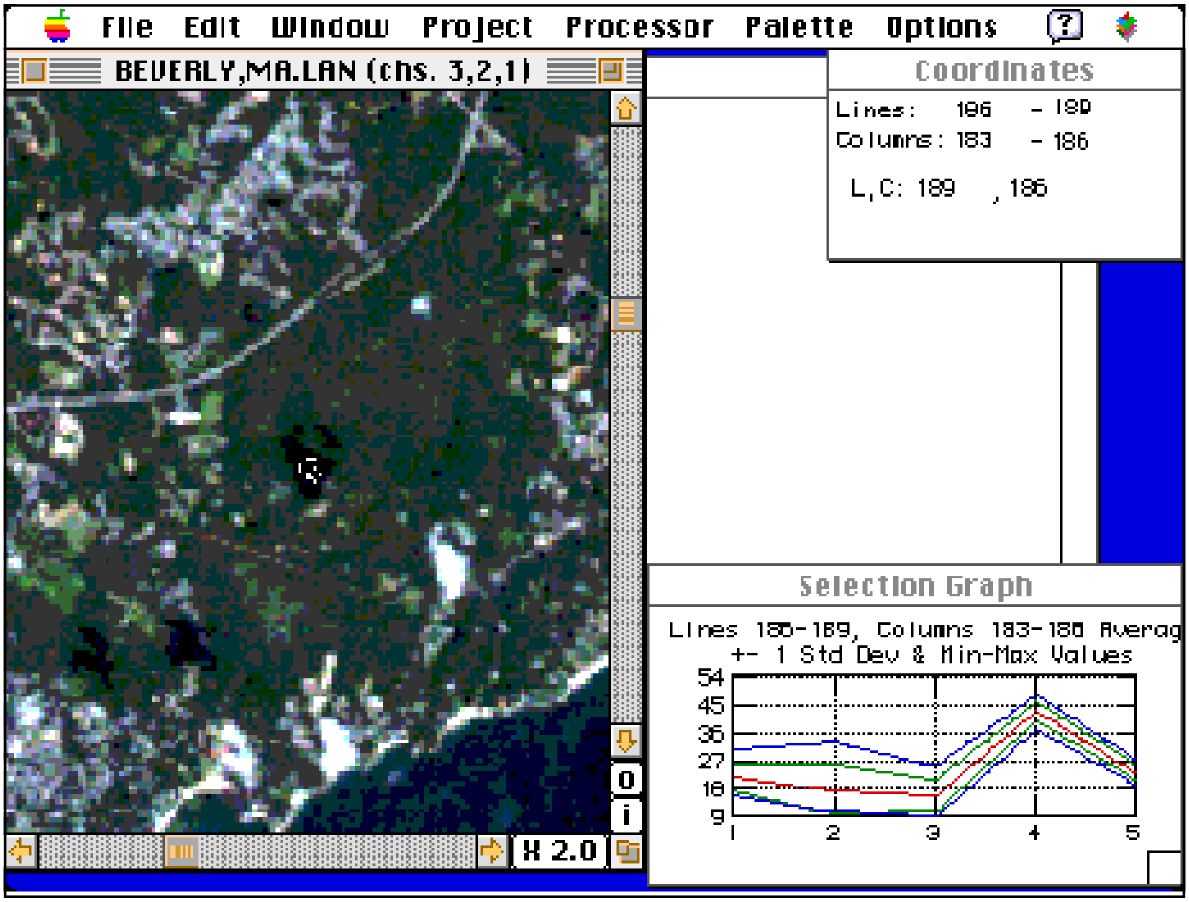
The very similar shapes strongly suggest that we are looking at clouds and their shadows. Note especially how closely the dark object in pair A corresponds to the light object in pair A in the figure below. These must be clouds and their shadows!



But let's be skeptical. What else could these dark regions be? Perhaps they are lakes! Let's get a histogram of one of these dark regions and save it. Then we'll get a new histogram of a known lake for comparison purposes. Here are the steps we can follow to prepare for a new discrimination exercise.

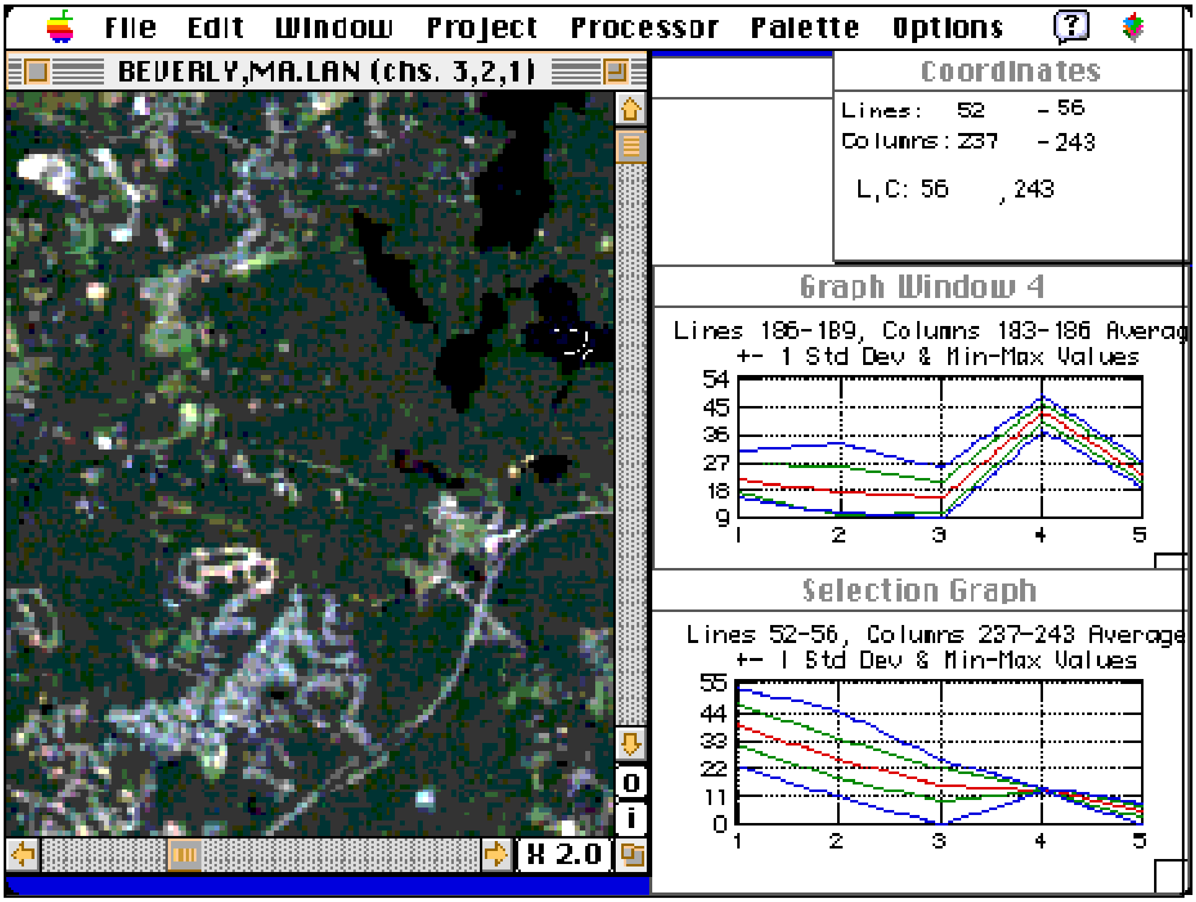
Click in the top graph window to activate it. Now click in the close box (upper left hand corner of window) to close this old histogram.

Click in the image window to activate it. Now select a rectangle of pixels from (L,C) = (186,183) through (L,C) = 189,186). This region corresponds to the dark region that may be a cloud shadow or a lake. You may wish to use a magnification of **X2.0** (or **X1.0**). Your screen should resemble the figure below.



When your screen resembles the figure above, move the selection graph from the bottom position to the top position (where the old graph used to be). Next choose **Keep Selection Graph** from the **Options** Menu. Now the top graph will remain constant always displaying the histogram of the possible cloud shadow. Re-size and position the new selection graph window below the top one.

Now let's go find a lake. Click on the image window to activate it. Then scroll up the image window and select the rectangle of pixels from (L,C) = (52,237) through (L,C) = (56,243). This region is definitely a lake as verified by ground truthing. The histogram of this lake region should appear in the bottom graph window. After selecting the known lake region your screen should resemble the figure below.



Note that the vertical scales on these two graphs are almost identical. We can compare these graphs directly and not worry about making mistakes due to relative similarities that are in fact different in absolute terms.

The histogram at the top is of the suspected shadow, and the histogram at the bottom is of the known lake. Are they the same? No. The lake is absorbing much more near-infrared energy (band 4) than is the shadow. The difference in reflectance on band 4 is about a factor of four (11 for the lake compared with 44 for the shadow). This difference makes sense as we would expect the trees in the shadow to reflect more infrared energy than a lake which is an excellent absorber of infrared energy.

Our exploration has come to an end. We have used histograms to identify clouds and their shadows. Now it's your turn to put histograms to use in helping you discover some interesting features of the Beverly image.

What's That?!

Using the reflectance histogram tool, explore the Beverly, MA image and see if you can find other examples of regions on the screen image that appear the same to your eyes but have very different histograms. You can display up to 12 histograms on the screen at one time for comparison of features.

Some possible explorations include:

Distinguishing beaches and shore, from very shallow water.

Differences between pavement on roads or parking lots and buildings.

Exploring similarly colored areas of vegetation that may have different histograms.

Examining in detail the transition from land to ocean. For example look at the histogram for one pixel at a time beginning with (138,397) and moving east through pixels (138,398), (138,399), (138,400), ..., (138,412).

If you find something interesting write a paragraph that provides a guide to exploring the interesting feature you have found. The guide should be complete enough that someone else can reproduce your explorations. Also include in the paragraph your analysis of the objects you are examining. Support any conclusions you make with arguments based on the histograms of the relevant objects. You can also copy histograms to the clipboard and paste them into another application, such as a word processor, to form a library of representative histograms of specific features. You can then investigate an unknown image and identify features by finding similar histograms to those in the library.